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Liberalisation, competition and innovation in the postal sector

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Abstract This paper empirically assesses the effect of liberalisation and competition on innovation in the postal sector. The analysis is restricted to end-to-end competition. The effect on the incentives to innovate of letter volume, public ownership and other control variables is also tested. Data on liberalisation, competition and innovation in the postal sector is collected for seventeen European countries over eleven years. Three measures are used as proxies for innovation: (1) an innovation index based on a survey conducted for this purpose; (2) the accumulated number of innovations (based on the same survey); and (3) labour productivity. We also develop a liberalisation index to measure the percentage of market liberalised (in terms of letter volume). Several models are estimated by GLS. In general, the models estimated have a high explanatory power. We find evidence that market liberalisation has a positive effect on innovation and that an increase in the market share of the competitors stimulates the investment in innovation, at least until the market share of the competitors reaches a certain threshold. Letter volume is also significant and has a positive impact on innovation. GDP per capita turns out to be significant and has a positive relationship with innovation in all the models estimated.

Keywords Liberalisation · Competition · Innovation · Postal sector

JEL Classification L10 · O30 · L87

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1 Introduction

Over the past decades, network industries have been going through a process of reform. Most network industries have evolved from being dominated by integrated state-owned monopolies to restructured industries with private sector participation and/or to partially or almost completely liberalised industries. The progressive liberalisation is definitely the most important aspect of this reform.

One of the major motivations for liberalisation is the belief that competition stimulates process innovation, product innovation, encourages efficiency and drives prices down. However, the effect of liberalisation and competition on innovation in the network industries was only empirically assessed recently by Jamasb and Pollitt (2011). Reforms are being pursued without fully understanding the actual results, in terms of innovation, of the measures already taken.

This article aims at filling this gap by investigating the effect of liberalisation and competition on incumbent's innovation in one of the network industries, the postal sector. We make a clear distinction between liberalisation, i.e. the relaxation or abolition of previous legal barriers to entry, and competition because liberalisation does not always translate in the development of competition.

To this end data on liberalisation, competition and innovation in the postal sector was collected for 17 European countries over 11 years. An econometric analysis was then performed. The explanatory variables of interest are the percentage of market liberalised (based on the evolution of the reserved area) and the market shares of the competitors. We control for letter volume, percentage of public ownership, gross domestic product (GDP) per capita and population density. Regarding the data on incumbent's innovation, 17 critical innovations were identified and the historical operators were inquired, through a survey, about their date of introduction. Based on this information an innovation index and the accumulated number of innovations were computed. In addition, labour productivity was also computed.

Several models were estimated by generalised least squares (GLS). The three innovation proxies mentioned above were used as dependent variable and the results were compared. In general, the models estimated have a high explanatory power. We find that the percentage of market liberalised is statistically significant, and has a positive effect on innovation. Regarding competition, the market share of the competitors is also significant and has a positive relationship with the investment in innovation. This result is valid at least until the market share of the competitors reaches a certain threshold, which was not attained yet in the postal sector. Letter volume is also significant and has a positive impact on innovation. GDP per capita turns out to be significant and to have a positive sign in all the models estimated. The percentage of public ownership seems to have a negative impact on innovation but this result is very preliminary since this variable has small variability.

The structure of this paper is as follows. First, the related literature is summarised and the hypotheses being tested are presented. Then, the data used is described in detail. Particular attention is given to the measures of innovation used, namely to the innovation index and to the liberalisation index. Next, the model and the estimation procedures are presented. Finally, the results are discussed. Section 7 concludes.

2 The impact of liberalisation and competition on innovation

The debate about the influence of the intensity of market competition on technical progress started with Schumpeter (1942) and continued with Arrow (1962). Schumpeter argues that monopoly favours the development of R&D activities because it provides the necessary cash flow to invest in such activities and reduces uncertainty in the market. Twenty years later, Arrow investigated the effects of market structure on the firm's incentives to invest in R&D to reduce costs. Arrow concluded that under competition the single firm gets more benefits from innovation than under monopoly. The intuition behind this result is that under monopoly, part of the benefits coming from innovation serve only to replace the monopolist's rents earned before innovating, i.e. the monopolist has greater opportunity costs of innovating. Grossman and Helpman (1991) and Romer (1990) support Schumpeter's view that monopoly is a precondition for innovation by arguing that firms innovate because they seek profitable opportunities that arise from monopoly. On the contrary, Nickell (1996) and Boone and Dijk (1998) support the existence of a positive relationship between competition and innovation.

Other authors have elaborated on the relationship between competition and innovation, introducing additional factors like the value of the innovation and the level of fixed and variable costs. Kamien and Schwartz (1975) and Kamien and Schwartz (1976) show that for inventions of small value, the absence of rivalry leads to the most rapid development, while a positive level of rivalry will achieve this for more valuable innovations. Loury (1979) finds that, under certain conditions, the incentives to invest in R&D of individual firms decrease as competition increases. The work developed by Lee and Wilde (1980) reaches rather different conclusions from Loury (1979). The authors conclude that an increase in rivalry increases the equilibrium individual R&D effort. In an attempt to reconcile this conclusion with Loury's earlier work, the authors show that if fixed costs in the R&D technology are larger than the variable costs, then an increase in competition leads to a decrease in the equilibrium level of firm investment in R&D.

Other authors have made a distinction between individual and industry innovation or investment in R&D, and find a positive effect of competition on aggregate innovation and a negative effect of competition on individual innovation (Cellini and Lambertini 2005; Blundell et al. 1999).

Between Schumpeter's followers and Arrow's defenders, a third group of authors emerged who have attempted to combine the previous arguments in order to rationalise the 'inverted-U' relationship between market concentration and R&D and technological advance found by some authors in the empirical studies. Scherer (1967) observes that the speed of technological research accelerates with rivalry, provided that the number of firms competing is not excessive. Scherer is the first to suggest an inverted-U relationship between competition and innovation. Later on, Boone (2000), Boone (2001) and Aghion et al. (2005) also find a nonlinear relationship between competition and innovation. Aghion et al. (2005) confirm the inverted-U relationship between intensity of competition and R&D incentives.

Felisberto (2007) develops and analyses a model of incumbent network operator when the incumbent is a monopolist as well as when it faces an entrant. The objectives of the incumbent are specified in a general manner to allow for revenue, profit and/or

welfare maximisation. The marginal cost of the incumbent is assumed to depend on the investment in new technologies. A strictly convex and decreasing cost function is assumed. The incumbent maximises its objective function with respect to prices and to investment in innovation. The entrant is assumed to maximise profits with respect to prices. The incumbent's incentives to innovate under monopoly and duopoly are compared. The main results are that the difference between the investment in innovation under monopoly and duopoly is governed by the incumbent's market share under duopoly and by the incumbent's elasticity of demand under monopoly and duopoly. For certain values of these variables, duopoly provides more incentives to innovate than monopoly. The relationship between the incumbent's market share and the incentives to innovate under duopoly is non-linear. Until a certain point the incumbent's market share has a positive impact on innovation under duopoly and from that point on it has a negative impact. The incumbent's elasticity of demand has a negative effect on the incentives to innovate under both market structures. Another major result is that the incentives to innovate decrease as the weight given to revenue and/or to profit increase. In other words, the more regulation can move the incumbent to act as a welfare maximiser, the larger the investment in innovation is.

In short, the literature on the relationship between competition and innovation does not have a clear answer as to whether competition stimulates innovation or not. Increased competition is said to have both positive and negative effects on innovation. The positive effect is a result of the firm's quest to optimize profits through increasing its efficiency and reducing its cost of production. Profitability pushes the development and adoption of more efficient technologies and processes. At the same time, competition decreases the rents of the monopolist and might reduce its market share. Therefore, revenue will also decrease. As a result, firms will have fewer resources to invest, for instance, in research and development. Similarly, they are also likely to encounter more difficulties when trying to recover potential investment into new technologies and new processes (not sufficient economies of scale)[1]. The lack of consensus is more apparent when the theoretical results are compared with the empirical results. The need for empirical evidence is undisputable.

The effect of liberalisation on innovation has barely been studied. Jamasb and Pollitt (2011) examine the effect of electricity reforms on patenting activity in the UK electricity sector. The results indicate that electricity related patents in non-nuclear and renewable technologies have increased in the post-liberalisation period. The authors attribute this trend to the increased commercialisation of the sector and argue that a lasting decline in R&D will in the longer run reduce technological progress and innovation in the sector.

We argue that the effect of liberalisation on innovation depends on the presence and intensity of natural barriers to entry on the supply side and on the mechanisms implemented to overcome those barriers. If there are no strong barriers to entry, then

[1] Information and Communications Technologies (ICTs) are having a significant impact in the postal sector and are leading to important changes in it, namely to the creation of new services and business areas. The pressure of ICTs on innovation in the enlarged postal value chain is not negligible, however in this paper, we focus on the traditional postal value chain and, hence, no further reference will be made to the effect of ICTs on innovation in the postal sector.

there is potential competition and, consequently a positive effect on innovation. If there are barriers to entry yet there is regulation capable of overcoming those barriers and making the threat of competition real, liberalisation will also have a positive impact on innovation. On the contrary, if there are barriers to entry and no mechanisms to make the threat of competition real, then liberalisation will not have any effect on innovation.

This paper tests the following hypotheses that follow from the literature: (1) liberalisation in the postal sector has stimulated operators to be more efficient, and therefore more innovative; (2) when the incumbents preserve a relatively high market share competition favours innovation, hence, a positive effect of end-to-end competition on innovation and efficiency is expected because the incumbents analysed here kept market shares of at least 90%; (3) the larger the amount of goods and services supplied (letter volume), the more innovative the operator is; and (4) a decrease in public ownership is expected to have a negative impact on innovation under the assumption that public ownership is the most likely ownership structure to promote welfare maximisation[2].

In the following section, the data used is described and analysed.

3 Data analysis

The dataset presented here results from the compilation of different sources and from a survey conducted by the author. It constitutes a unique source of information for analysing the liberalisation process, the development of competition, and the development of incumbents' innovation in the postal sector in the last decade.

We collected data to measure the degree of liberalisation and competition in the postal market, and the innovativeness of the incumbents (including the letter mail volume and the average number of employees). Some additional variables, namely the percentage of capital owned by the state, population density and GDP per capita, were also collected.

All these variables were collected for the period between 1995 and 2005 (some were also collected for 2006), in 17 European countries and operators (Table 1).

The data used to build the liberalisation index is available in several studies mandated by the European Commission, as well as the regulators' reports, the annual reports of the operators, and the International Post Corporation (IPC) regulatory database. The same sources were used to collect the data on the degree of competition, i.e. market shares.

The data necessary to build the innovation index and the accumulated number of innovations, two of the three measures of innovation used, was collected through a

[2] As mentioned before, Felisberto (2007) concludes that the more regulation can move the incumbent to act as a welfare maximiser, the larger the investment in innovation is, i.e. welfare maximisation stimulates innovation. Assuming that a public enterprise whose managers operate under a charter directed toward consumer welfare and efficiency (in pricing) may be concerned about welfare maximisation, i.e. assuming that public ownership is the most likely ownership structure to promote social welfare maximisation it follows that a decrease in public ownership is expected to have a negative impact on innovation.

Table 1 Countries and operators included in sample

Country	Operator
Bulgaria (BG)	Bulgarian Posts plc
Croatia (HR)	Hrvatska pošta d.d.
Estonia (EE)	Eesti Post Ltd
Finland (FI)	Itella Oyj
France (FR)	La Poste
Germany (DE)	Deutsche Post AG
Ireland (IE)	An Post
Italy (IT)	Poste Italiane S.p.A.
Latvia (LV)	Latvijas Pasts
Poland (PL)	Poczta Polska
Portugal (PT)	CTT— Correios de Portugal, S.A.
Romania (RO)	C.N. Posta Romana S.A.
Spain (ES)	Correos y Telégrafos S.A.
Sweden (SE)	Posten AB
Switzerland (CH)	Die Post/La Poste/La Posta
The Netherlands (NL)	TNT Post
United Kingdom (UK)	Royal Mail Group PLC

survey (see Appendix A). In that survey the incumbents were asked about the date of introduction of 17 critical innovations identified by the author.

We first analyse the different measures of innovation and the liberalisation index. After, we examine the degree of competition and the remaining variables.

3.1 Measures of innovation

Three proxies for innovation are used: an innovation index (*inindex*), the accumulated number of innovations (*accuminno*), and labour productivity (*itemperempl*).

Data on upstream collection, mail processing and transportation innovations introduced by the incumbents surveyed was collected to build the innovation index and the accumulated number of innovations.

The innovation index and the accumulated number of innovations are based on the date of introduction of the following seventeen critical innovations: optimisation of collection routes (using software); hybrid mail; digital stamp; radio Frequency Identification (RFID) used to identify trucks; RFID used to identify trolleys; RFID used to identify trays or bags; RFID used to monitor the performance of the letter post; automated sorting machines using Optical Character Recognition (OCR) that can read whole front side of the letter; OCR that can read hand-written whole addresses; OCR that can read hand-written postal codes; OCR that can read machine written postal codes and whole addresses; video coded address reading equipment—online coding; video coded address reading equipment—scanning and remote coding (off-line video coding equipment); automated sequence sorting to delivery route; automatic tray handling systems; automated guided vehicles (AGV); and route planning and optimization software for delivery.

These 17 critical innovations were identified through the literature (Arthur D. Little Limited 2004; WIK 2004; NERA 2004; Pricewaterhousecoopers 1997), the annual reports of the operators, and interviews with experts in the postal sector[3]. First, the ensemble of the more significant innovations was listed. Second, the more recent innovations and the ones that have more impact on costs and costumers' satisfaction were selected.

The innovation index measures the innovativeness in the postal sector. It corresponds to the average delay or advance, in years, in introducing the critical innovations. The innovation index for country j in year t $\left(X_{jt}\right)$ is computed as follows:

$$X_{jt} = \sum_{i=1}^{18} \Omega_i \left(t, T_i, T_{ij}\right) \Phi_i \left(t, T_i\right)$$

where T_{ij} is the year in which innovation i was introduced in country j, T_i is the year in which the innovation was first introduced in any country (so $T_i \leq T_{ij}$), and where $\Omega_i \left(t, T_i, T_{ij}\right) = \begin{cases} T_i - t & if\ t < T_{ij} \\ t - T_{ij} & if\ t \geq T_{ij} \end{cases}$ and $\Phi_i \left(t, T_i\right) = \begin{cases} 0 & if\ t \leq T_i \\ 1 & if\ t > T_i \end{cases}$.

If a certain innovation was already introduced by a country (called the pioneer country) and the country being analysed did not introduce that innovation yet, then the latter will be penalised with the number of years that elapsed from the year the innovation was first introduced until the year in question. On the contrary, if the country being analysed has already introduced a certain innovation, then it is beneficed with the number of years that elapsed from the year that country introduced the innovation until the year in question.

In this way, it was computed for each country and each year the number of years the country is, on average, late or advanced in introducing the critical innovations (the same weight was given to all innovations). For example, consider only two innovations A and B (instead of 18 innovations). Innovation A was introduced for the first time in 1995, and innovation B in 2002. Country J introduced innovation A in 2000, and innovation B in 2004. The innovation index of country J in 1999 is $-4(=(1995-1999)+0)$, in 2000 is $0(=0+0)$, in 2001 is $1(=(2001-2000)+0)$, in 2002 is $2(=(2002-2000)+0)$, in 2003 is $2(=(2003-2000)+(2002-2003))$, and so on.

The pioneer country is identified among the 17 countries plus the United States of America[4].

In our sample, the innovation index ranges from -18 until 18, which are the maximum average delay and the maximum average advance a country can have,

[3] Mr. Josef Bösch, CEO Postmail, Swiss Post; Mr. Michel Kunz, CEO Logistics, Swiss Post; Mr. Peter Stoop, Responsible Business Technology Center, Swiss Post; Mr. Kenneth Lützelschwab, Responsible REMA project, Swiss Post; Mr. Pedro Saldanha, Business Strategy and Development, CTT Correios de Portugal, S.A.

[4] The USA is not included in the econometric analysis because it does not have end-to-end competition. However, the USA was considered when deciding the date of introduction by the pioneering country because, traditionally, the USA has indeed been the pioneer country introducing new technologies and processes.

respectively. This measure is richer than the simple count of the number of innovations because it takes into account whether the innovation is more or less recent, i.e. it takes into account the year in which the innovation was first introduced. As explained before, for each year that elapses without the introduction of an innovation, the country is penalised. Hence, in order to ensure a symmetric treatment of the innovations that were already introduced relative to the ones that were not, a country must benefit for each year that elapses from the introduction of an innovation.

The countries with larger technological delay are Bulgaria, Estonia, Croatia and Latvia. Italy, Romania and the United Kingdom used to have an innovation index much lower than the average. However, in 2003, both the United Kingdom and Italy invert the negative trend and, in 2004, Romania does it too. Today the United Kingdom is above the average, Italy just reached the average and Romania is very close to it. The innovation delay/advance introducing the critical innovations of the incumbents from Switzerland, Finland, Ireland, Poland and Portugal have been around the average throughout the period of study. Spain, Germany, France, The Netherlands and Sweden have registered an innovation index above the average. Figure 1 shows the evolution of the innovation index for the ensemble of the countries.

We now analyse the second measure of innovation: the accumulated number of innovations. This variable corresponds to the number of innovations, among the critical innovations, that were implemented until the year in analysis. The evolution of this variable is consistent with the evolution of the innovation index.

Figure 2 displays the evolution of the accumulated number of innovations for the 17 countries.

Finally, we consider the third measure of innovation: labour productivity. This variable is equal to the letter mail volume (in thousands) divided by the average number of employees.

The data on the volume of letter mail in billions of items (*tvolume*), which includes domestic and international correspondence, registered items, insured letters, newspapers as well as addressed and unaddressed advertising items, is available through the UPU database.

There have been some small fluctuations in the volumes yet not significant ones (Fig. 3). The impact of electronic substitution on mail volumes has been weaker than predicted by some operators. The expectations are that letter post will become more a means of distribution of direct mail than for exchange of correspondence. The direct mail growth should partially compensate for the loss of correspondence and transaction mail (WIK 2005).

The French market is the one with the larger letter mail volume, followed by the British and the German markets. For the remaining countries, the letter mail volumes are below 7 billion items per year, in 2005. France, the United Kingdom and Portugal have experienced growing mail volumes. The total average has also been increasing slightly.

The average number of employees (corresponds to the whole company since there was no data available by segments and includes permanent employees and employees with a term contract) in thousands (*empl*) was also collected from the UPU database

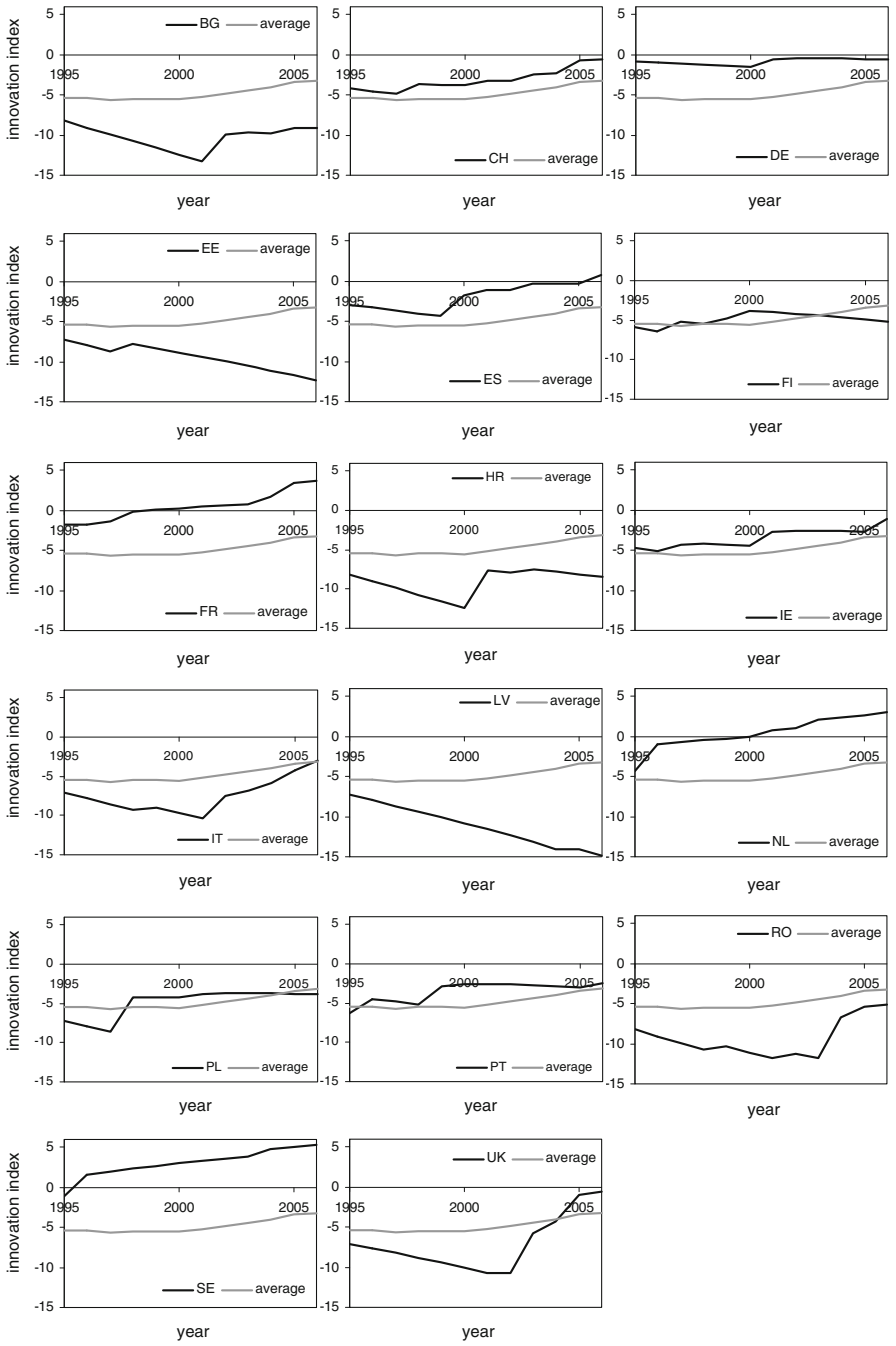

Fig. 1 Innovation index

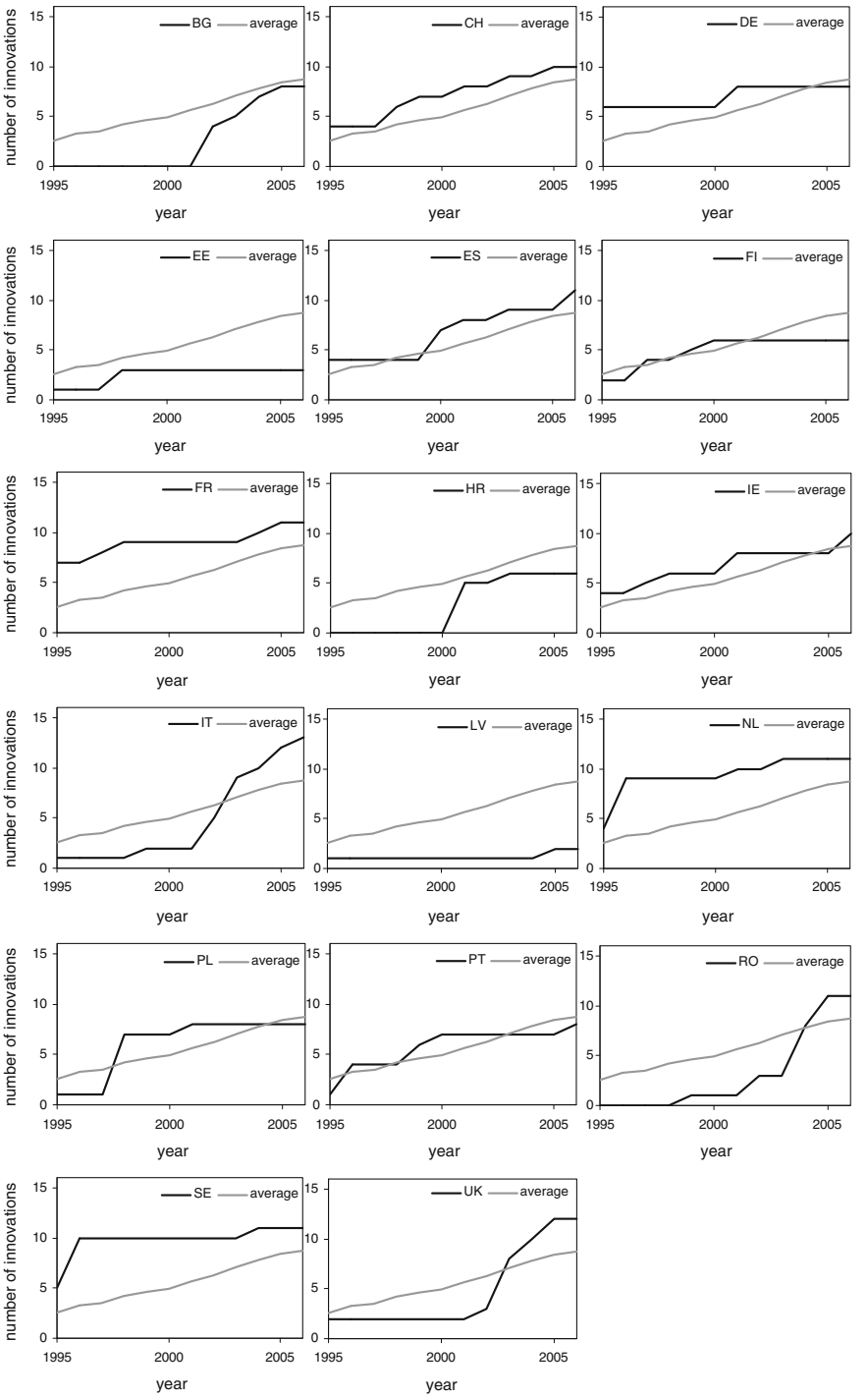

Fig. 2 Accumulated number of innovations

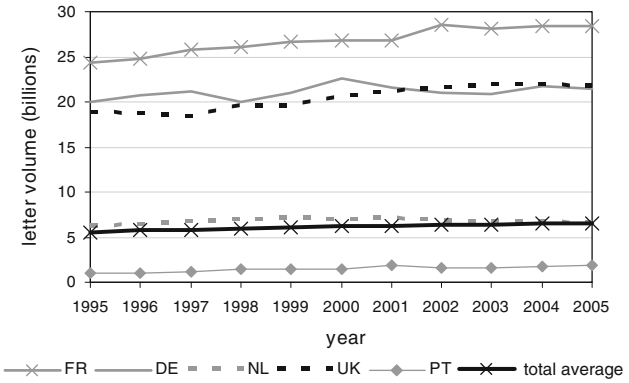

Fig. 3 Evolution of letter mail volumes

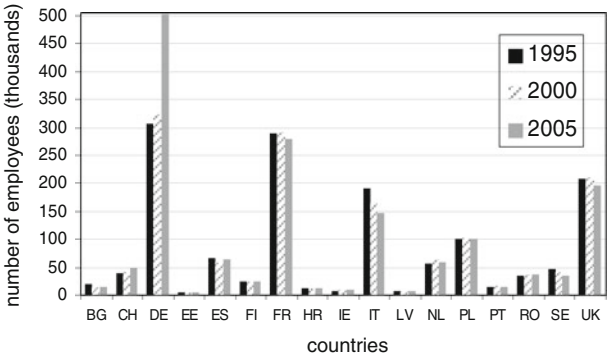

Fig. 4 Average number of employees for the years 1995, 2000, and 2005

except for Latvia Post. The average number of employees of Latvia Post was collected from Amadeus database.

The countries with the largest number of employees are Germany, France and the United Kingdom (Fig. 4). These three countries are also the ones with larger volumes as observed before. Italy stands out because it has a relatively large number of employees although its letter mail volume is around the average of the countries being studied. The same happens with Poland the letter mail volumes of which are approximately half of the average, whereas its number of employees is very close to the average.

The measure 'labour productivity' presents some drawbacks, which are important to keep in mind. First, labour productivity was computed with the total number of employees and not only the employees working in the letter segment. The consequences of this is that a postal operator with a large diversification of products and where financial services, for instance, have a large weight will have a relatively small labour productivity. Second, an increase in mail volume does not trigger a proportional increase in the number of employees because the postal services are characterised by economies of scale and scope. Therefore, comparisons among countries with different mail volumes have to be cautious.

It must also be considered that sometimes firms cannot lay-off as soon as there is a decrease in volumes, which may cause a decrease in labour productivity. The evolution of labour productivity is presented in Fig. 5.

Since labour productivity is generated from completely different data than the innovation index, it is interesting to compare both measures.

Bulgaria has a labour productivity below the average, which is consistent with the technological delay introducing the 17 innovations mentioned before. In the same situation are: Estonia, Croatia, Italy, Latvia and Romania. In Estonia, however, the innovation index is negatively deviating more and more from the average while labour productivity is approaching the average. In Latvia, the innovation index is also negatively deviating more and more from the average whereas labour productivity remains more or less stable.

The evolution of labour productivity for the French, Dutch, Spanish, Swedish, Finnish and Irish incumbents is also consistent with the evolution of the innovation index. The French, Dutch, Spanish and Swedish incumbents have an innovation index above the average and their labour productivity is larger than the average labour productivity. In Finland and Ireland, both measures of innovation have always been very close to the average.

In Germany, the innovation index has always been above the average, whereas labour productivity has been decreasing and is now below the average.

Switzerland and Portugal have registered, through the years studied, an innovation index close to the average, while their labour productivity has always been above the average. In Portugal, labour productivity has been steadily increasing.

In Poland, there is a divergence between the two indexes: the innovation delay is close to the average while labour productivity has always been below the average.

Finally, in the United Kingdom, the innovation index was very low until 2003, when it started to increase, while labour productivity has always been above the average.

3.2 Measuring the degree of liberalisation

In 1998, the European Postal Directive 97/67/EC was implemented, which sets the maximum weight limit of the reserved area at 350 grams for items of correspondence and the price limit at five times the basic tariff for a first class letter in the lowest weight band. The directive 2002/39/EC reduces the reserved area to items of correspondence that weigh less than 100 grams and cost less than three times the basic tariff as of January 1st, 2003, and to 50 grams and two and a half times the basic tariff as of January 1st, 2006. Furthermore, the outgoing cross-border mail is required to open to competition on January 1st, 2006 but exceptions are accepted if needed to ensure universal service. Directive 2002/39/EC sets the full market opening of the postal markets for January 1st, 2009, subject to confirmation by the European Parliament and the Council. In 2007, the European Parliament voted to delay the full market opening until January 1st, 2011. The new member states and posts that work in difficult terrain can delay full liberalisation for a further two years.

The aim of the European Commission is the gradual market opening of the postal sector within the European Union. Besides the definition of the maximum reserved

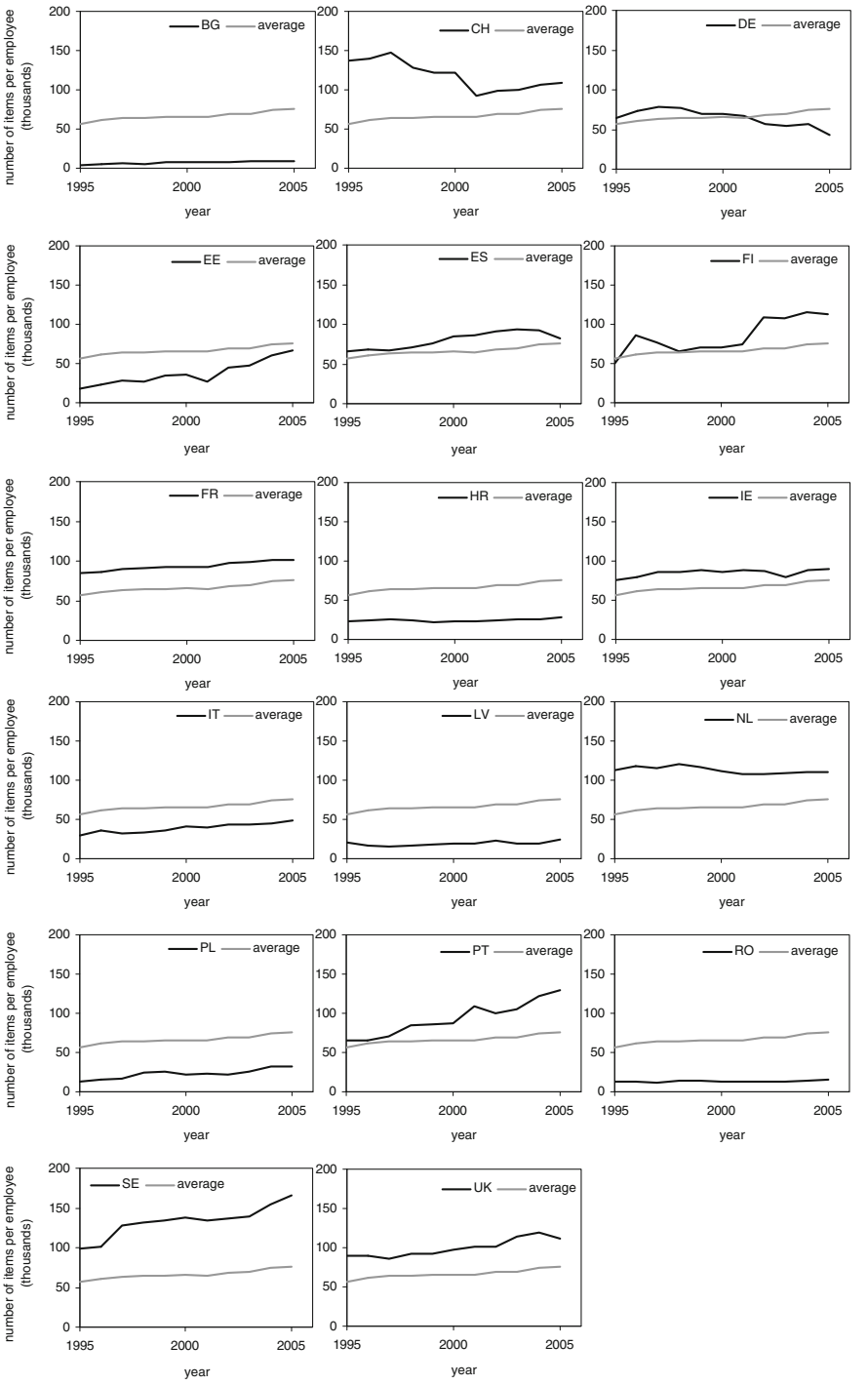

Fig. 5 Labour productivity (thousands of items per employee)

Table 2 Correspondence between reserved area and percentage of letter mail volume liberalised (domestic and inbound cross border correspondence)

Weight limit of the reserved area (g)	Percentage of mail volume
>0	100
>50	25[a]
>100	18[a]
>150	14
>200	10
>350	7[a]
>500	2
>1000	1
>2000	0

[a] WIK (2004)

area the directives also set a minimum universal service, the conditions determining the provision of non-reserved services and access to the network, tariff principles and the transparency of accounts, minimums for quality of service, the harmonisation of technical standards. Moreover, directive 97/67/EC required the creation of independent national regulatory authorities.

The letter post items can be divided into four categories: items of correspondence, addressed printed matter, newspapers and un-addressed printed matter (i.e. un-addressed direct mail). Items of correspondence include letters, postcards and transaction mail such as bills and bank statements. Included in addressed printed matter are: addressed direct mail, catalogues and magazines or periodicals.

The reserved area includes the clearance, sorting, transport and delivery of items of domestic and incoming cross-border correspondence. It may also include direct mail (addressed items only) and outgoing cross-border mail falling in the same weight and price limits to the extent necessary to ensure the maintenance of universal service. There are nevertheless exceptions to this reserved area. Among the countries at study, Germany and Ireland exclude the collection and transportation of mail to a post office for final delivery from the reserved area. France, Germany, Italy, The Netherlands, Portugal and Spain exempt 'special services' (i.e. services that are 'distinct from the universal service') from the reserved area. Also, Portugal does not include 'day certain' delivery in the reserved area (WIK 2006).

The liberalisation index (*mktliberalised*) developed by the author to measure the degree of liberalisation in the postal sector corresponds to the percentage of letter mail volume opened to competition. The index refers only to items of correspondence and addressed direct mail. It takes into account whether the following categories are part of the reserved area: domestic and inbound cross-border correspondence (weight criteria transformed in percentage of mail liberalised according to Table 2); local intra-city mail; direct mail; outbound cross-border correspondence.

Each category was given a weight according to the composition of the mail market in physical terms (Table 3).

Before the Postal Directive 97/67/EC, the incumbents retained monopolies for letters, generally up to 1 or 2 kilograms. It was assumed that the maximum reserved area

Table 3 Composition of the mail market in physical terms

	Domestic and inbound CB (%)	Direct mail (%)	Outbound CB (%)
FR	74	23	2
DE	62	37	2
ES	75	21	4
SE	73	23	4
CH	66	31	3
NL	76	20	4
UK	69	28	3
US	73	26	0
PT	81	15	4
BG	88	10	1
CZ	76	21	3
HR	62	37	1
EE	85	11	4
FI	77	22	1
IE	82	7	11
IT	67	32	1
LV	93	4	4
PL	92	5	3
RO	75	24	2

Source ECORYS (2005)

for domestic and incoming cross-border mail was two kilograms. Figure 6 displays the evolution of the liberalisation index for the 17 countries.

Spain was, among the countries at study, the first one to liberalise a considerable part of its letter market. In the 1960s, the intra-city mail in Spain was fully opened to competition. For decades, the reserved area in Spain has been restricted to letters and postcards that are inter-urban or international. Therefore, the Spanish market is one of the most competitive European postal markets.

The liberalisation process in Sweden started in 1985 when the Swedish government established quality and profitability as the objectives of Posten. Posten was given more freedom in the capital markets in 1987 and measures of consumer satisfaction were put in place. Five years later, Posten was given the freedom to set prices within certain limits, and in 1993 the letter monopoly was abolished (Price Waterhouse 1997). Since then, the market share of the incumbent (Posten) has been declining. Today, the most important private operator (CityMail) has a market share of approximately 8.5%.

Estonia and Finland have also fully liberalised their postal market. Finland took the decision to fully liberalise the mail market in 1991, which took effect in 1994. Estonia liberalised its mail market in 2002. However, competition has not developed in these countries due mainly to restrictive licence conditions and taxation.

In the United Kingdom, the Postal Services Act 2000 abolished the reserved area and from January 1st, 2006, the Postal Services Commission ('Postcomm') grants licenses to all operators subject only to compliance with certain essential require-

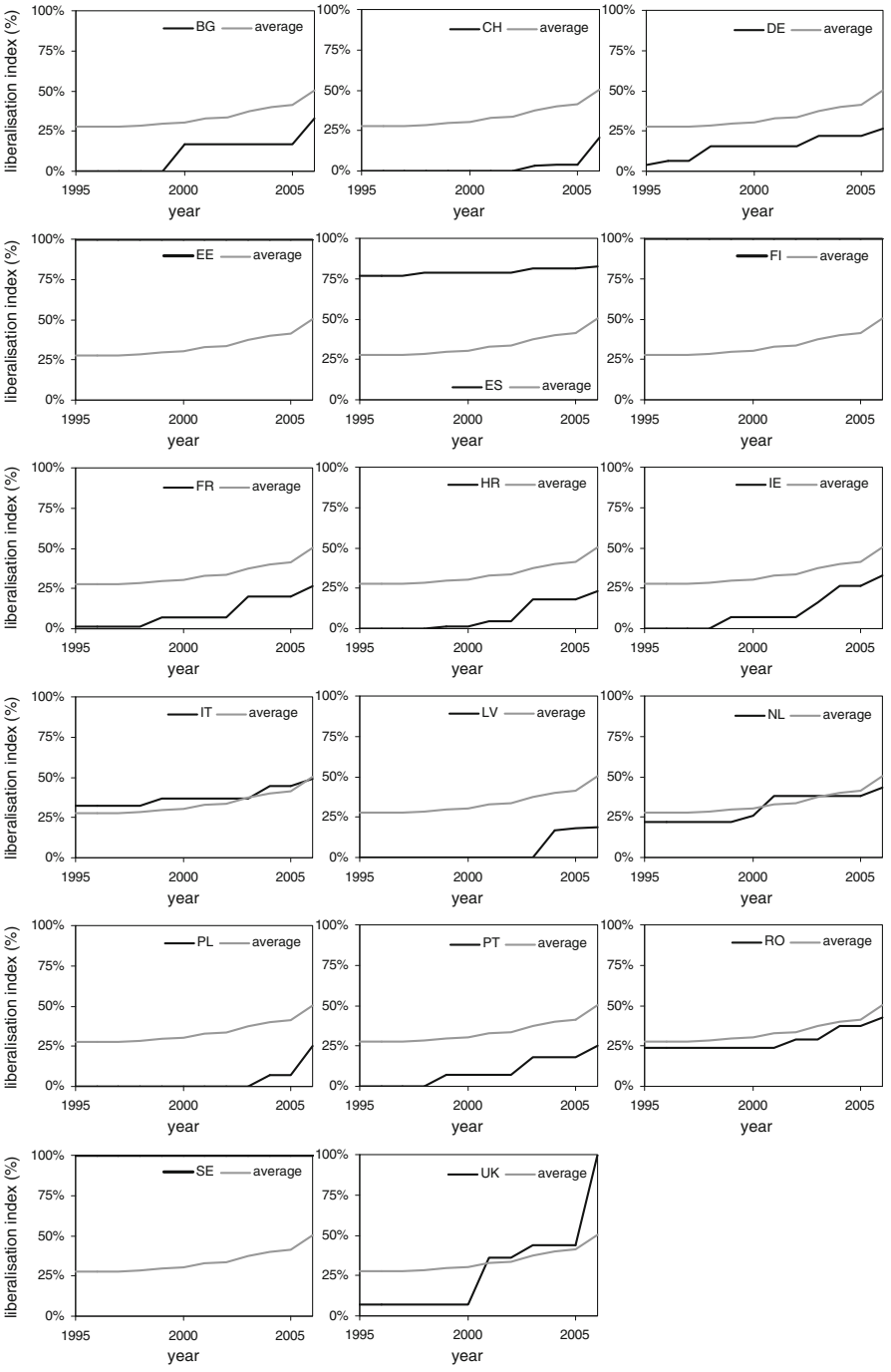

Fig. 6 Liberalisation index

ments, instead of only bulk mail providers and certain other special categories of postal services operators as before 2006 (Eccles and Kuipers 2006).

In 2004, the Dutch Minister of Economic Affairs, Laurens-Jan Brinkhorst published a paper on the future of postal policy in the Netherlands[5]. In this paper, he defends the full market opening of the Dutch market in 2007, but conditioned on the full liberalisation of the British and German markets. He justifies this position by the need to create a level playing field (WIK 2004).

In Germany, letter items weighting more than 200 grams became open to competition in 1998. Regarding direct mail, the weight limit was firstly reduced in 1995 to 250 grams, then in 1996 to 100 grams and finally in 1998 to 50 grams.

The liberalisation of direct mail is particularly interesting because direct mail represents a great share of the total volume of letter mail. Eight of the countries analysed here—Croatia, France, Germany, Ireland, Latvia, Poland, Portugal and Switzerland—have maintained a reserved area over direct mail (IPC 2007). In Italy and The Netherlands, addressed direct mail is liberalised and substantial competition can be observed in this segment.

The definition of direct mail is not homogeneous in all the countries. In the Netherlands, direct mail corresponds only to wholly printed matter whereas, for instance, in Germany items of direct mail can differ in respect to specific elements. In Spain and Italy, direct mail is defined as items whose body is 'essentially identical'. The Directive considers as direct mail the advertising items where the nature of the message is the same even if there are other elements specific to each item (WIK 2006).

Among the countries at study, seven also reserve outgoing mail. These countries are Bulgaria, Italy Latvia, Poland, Portugal, Romania and Spain (IPC 2007).

3.3 The degree of competition

The degree of competition is measured through the market share of the competitor postal operators (in terms of volume) (*mktshareE*) in addressed mail delivery, including both reserved and non-reserved areas. The sources of the market share of the entrants are the following: ECORYS (2005), WIK (2004), Bundesnetzagentur (2006), and the Swedish regulator.

Owing to the lack of quantitative data on upstream and downstream access, the analysis is restrict to end-to-end competition.

mktshareE is a discrete variable that assumes the values 1, 3, 5, 7, 9 and 11. These values correspond to the mid point of the interval to which belongs the market share of the entrants. For example, if entrants have a market share that lies on the interval [0%,2%] then *mktshareE* assumes the value 1. If entrants have a market share that lies on the interval (2%,4%] then *mktshareE* assumes the value 3, and so on. Figure 7 illustrates the evolution of the market share of the entrants between 1995 and 2005.

In the majority of the countries under study, the entrants' market share does not exceed the 2%.

5 " Postal Memorandum " available at http://www.ez.nl/content.jsp?objectid=20863 [8/10/2007].

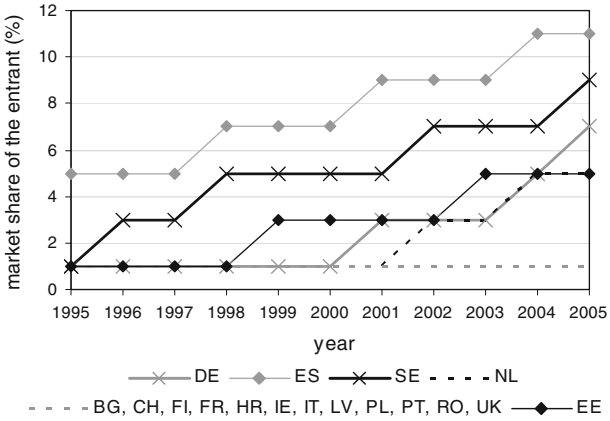

Fig. 7 Evolution of entrants' market share

Spain is the country where competition is highest, followed by Sweden. Although Finland and Estonia liberalised their mail markets some years ago, the restrictive licence conditions and taxation policy has restricted the development of competition. In both countries, potential entrants are required to provide postal services in the whole territory of the country[6]. In Finland, potential entrants can opt for a restricted license that implies an additional turnover tax of 5–20%, depending on the territorial coverage of mail delivery.

The license requirements to deliver addressed mail in Sweden are not restrictive. Moreover, there are no licence requirements to deliver catalogues, magazines and unaddressed mail. However, not a lot of competition has developed, and the incumbent still has a very dominant position currently. This slow development of competition is related to different factors. Initially, the legislation was not adapted to support or create the preconditions for competition. Also, CityMail (the largest competitor of Posten AB) faced numerous internal problems that limited its business development and expansion. Finally, Sweden has a large territory with a low population density, which creates barriers to entry (ECORYS 2005).

After Spain and Sweden, the countries where competition is most developed are Germany, The Netherlands and Estonia.

3.4 Other variables

In addition to the main variables of interest described above, we also collected data on the following control variables: percentage of public ownership, population density, and GDP *per capita*.

The share of equity owned directly or indirectly by central governments (*publick*) was collected from the operators' annual reports, the IPC Postal regulatory databases, and the operators' websites. Among the countries at study, only Deutsche Post and

[6] With the exception of the Aland islands in Finland.

Table 4 Variables' description

Variable	Description
inindex	Innovation index
accuminno	Accumulated number of innovations
itemperempl	Labour productivity
tvolume	Volume of letter mail (in billions of items)
empl	Average number of employees (includes permanent employees and employees with a term contract) (in thousands)
mktliberalised	Liberalisation index (measures the degree of liberalisation, i.e the percentage of letter mail volume opened to competition)
mktshareE	Market share of the competitor postal operators (in terms of volume)
publick	Share of equity owned directly or indirectly by central governments
popdens	Population density
gdppercap	GDP *per capita*

TNT Post are partially privatised. In 2005, the Deutsche government held 45% of the shares of Deutsche Post and only 10% of the shares of TNT Post were owned (directly or indirectly) by the Dutch government.

Population (in millions) was collected from Eurostat and countries' area is available at the UPU database. These two variables were used to build the variable population density (*popdens*). Population density is in number of habitants per squared kilometre. France, Germany, UK and Italy are the countries with the greatest populations. These countries, except France, are among the four countries with the highest population density. The Netherlands is the country with the highest population density.

The GDP at 1995 prices was collected from Eurostat's statistics and used to compute the variable GDP *per capita* (*gdppercap*). GDP *per capita* is in thousands of euros per habitant. The countries with the highest GDPs are Germany, France, the United Kingdom and Italy, whereas the countries with the largest GDP *per capita* are Switzerland, Sweden, Finland, Germany and the Netherlands.

Finally, both exchange rates and inflation rates are from Eurostat.

Table 4 summarises and describes the variables involved in this study. The detailed descriptive statistics are presented in Appendix B, Table 5.

4 The model

In this section, we present the econometric model estimated to test the hypotheses presented in Sect. 2. Its general form is:

$$Innovation_{it} = \alpha + \beta_1 X_{it} + \beta_2 mktliberalised_{i,t-1} + \beta_3 mktliberalised_{i,t+1} + \beta_4 C_{it} + e_{it}$$

where t represents years, i denotes countries, α is a constant term, X_{it} is a vector of exogenous explanatory variables, and C_{it} is the vector of control variables.

The contemporaneous explanatory variables included in the vector X_{it} are: *mktliberalised* and *mktshareE*. Vector C_{it} includes: *publick*, *tvolume*, *popdens*, and *gdppercap*.

This model is estimated for the three different measures of innovation presented before, which are: the innovation index (*inindex*), the accumulated number of innovation (*accuminno*) and labour productivity (*itemperempl*).

The aim of lagging and forwarding *mktliberalised* one period is to test if firms react with delay to liberalisation policies or if firms anticipate future changes regarding the market liberalisation, respectively.

The correlation matrix between independent variables is displayed in Appendix B, Table 6.

We start by estimating a specification only with the contemporaneous variables and control variables. Then, a second model that excludes *popdens*, because of its correlation with *mktliberalised*, is estimated. After, we estimate a model that excludes *gdppercap* from the second model because of its correlation with *tvolume*. We then investigate if the t-statistics are being affected by the correlation between *mktliberalised* and *mktshareE* by estimating two other models: one with *mktliberalised*, *publick*, and *tvolume* as explanatory variables, and another one with *mktshareE*, *publick*, and *tvolume* as explanatory variables.

5 Estimation procedures

First, the models were tested for the presence of heteroskedasticity and correlation between and within panels. Table 7, in Appendix B, summarises the results of the tests performed.

By plotting the Ordinary Least Square (OLS) residuals, it is possible to see (independently of the variable used as proxy for innovation) that the means and the dispersion are different across countries. This finding confirms the existence of a panel structure. Also, the fact that the second moments are different across countries is a first indication of a problem of heteroskedasticity.

A likelihood-ratio test (lrtest hetero) was performed to determine the presence of heteroskedasticity. In all the models, the null hypothesis of homoskedasticity is rejected, which indicates the presence of heteroskedasticity. For the purpose of learning more about the type of heteroskedasticity, namely to test for inter-individuals heteroskedasticity, a modified Wald test was performed (xttest3). The rejection of the null hypotheses confirms the existence of inter-individuals heteroskedasticity.

It is not possible to perform a Breusch–Pagan test (xttest2) to check for correlation across panels because the number of firms is larger than the number of time periods being analysed (i.e. $N > T$). Nevertheless, we will assume that there is spatial correlation in the errors since it is very common to find this type of correlation in panel data models. The first order autocorrelation test of Wooldridge (xtserial) indicates the presence of serial autocorrelation in the three models since the null hypothesis of independence of the residuals is rejected.

In the presence of autocorrelation within panels, cross-sectional correlation and heteroskedasticity, the most appropriated estimation procedures are Generalised Least

Squares (GLS) and Prais-Winsten estimation with Panel Corrected Standard Errors (PW-PCSE). The models presented in Appendix B were estimated by GLS[7].

GLS allows estimation in the presence of a first order autoregressive process (AR(1)) within panels and cross-sectional correlation, and heteroskedasticity across panels. The coefficient of the AR(1) process can be specified as being common to all the panels or as being specific to each panel. We assume that the AR(1) coefficient is specific to each model.

Finally, a Granger causality test was performed (using 3 lags). An equation in which y was regressed on lagged values of y and lagged values of an additional variable x was estimated, and the null hypothesis that x does not Granger-cause y was evaluated. It was concluded that the null hypothesis that all coefficients of lag of *mktliberalised* are equal to zero should be rejected. Therefore, *mktliberalised* Granger-cause *inindex*.

However, regarding *mktshareE*, the null hypotheses that all coefficients of lag of *mktshareE* are equal to 0 cannot be rejected. This result must be interpreted carefully. First, there is an important flaw of panel Granger tests: rejecting the presence of a causal relationship for an entire group of observations when a subset of the sample does actually manifest the hypothesized causal relationship. Second, the fact that x does not Granger-cause y does not necessarily imply that y is independent of x. Granger causality only refers to the capacity of lags of x to forecast y. Hence, it was decided to leave *mktshareE* has an explanatory variable in the majority of the models estimated (keeping in mind that we may be facing a causal relation in the inverse sense—as defended by some authors—or a simple correlation). Furthermore, it was decided to estimate one model without this explanatory variable, in order to compare the results.

6 Results

In this section, the results are presented and discussed. A total of 21 models were estimated, using the innovation index, the accumulated number of innovations and labour productivity as dependent variables. In all the models estimated, the explanatory variables are found to be jointly significant.

The use of one innovation measure instead of another does not originate significantly different results. Hence, only the models that have the innovation index as dependent variable are reported in Appendix B (Table 8). Among the reported models the most robust one is model 3, and hereafter we refer to it as the selected model (the results obtained using the other proxies for innovation and the same explanatory variables as in model 3 support the results of this model).

The fact that the use of the different proxies for innovation does not originate; significantly different results shows that the developed innovation index is a good measure of innovation and gives certain warranties about the quality of the models estimated.

[7] These models were also estimated using PW-PCSE, but given the similarity of the results PW-PCSE estimations will not be reported here.

As it will be seen in more detail the first hypothesis (liberalisation has a positive effect on innovation), the second hypothesis (competition stimulates innovation) and the third hypothesis (quantities have a positive effect on innovation) from section II are accepted. The fourth hypothesis (public ownership has a positive impact on innovation) is rejected.

The selected model indicates a positive effect of liberalisation on innovation. The degree of liberalisation is statistically significant and has a positive impact on innovation, i.e. the estimated coefficient has the expected sign. The response of the incumbent to liberalisation policies occurs either in the same year the policy comes into force or in the years that precede that event, that is, the incumbents may react to liberalisation policies in advance. Nevertheless, there is less evidence concerning the effect of the percentage of market liberalised forward one period ($mktliberalised_{t+1}$) than of the contemporaneous percentage of market liberalised ($mktliberalised_t$). It may happen that some of the investments in innovation are decided in advance but they are only observable in the following year(s).

The actual competition, measured by the market share of the entrants, is statistically significant in all the models reported, and also has a positive effect on innovation. As predicted, there is evidence that the larger the market share of the entrants, the more innovative the incumbent is, at least until the market share of the entrants reaches a certain threshold.

Concerning the letter volume handled by the operators, the selected model shows a strong statistical evidence of a positive impact of letter volume on the incentives to innovate.

In all the models reported, the percentage of public ownership is always statistically significant but contrary to what was expected, the percentage of public ownership is negatively related to innovation. This does not necessarily mean that welfare maximisation does not stimulate innovation. It can mean that public ownership is not the ownership structure most likely to promote welfare maximisation. In other words, under the hypothesis that public ownership creates more incentives to innovate than private ownership is the assumption that governments are likely to maximise social welfare, which in reality may not always be true. Moreover, the variable 'percentage of public ownership' presents almost no variability, and therefore, all the results related to this variable should be seen as preliminary and taken with considerable caution.

GDP *per capita* is always statistically significant and has a positive sign, which means that the larger the GDP *per capita*, the more innovative the incumbent is. This reflects the fact that in the most developed economies and countries with higher standards of living, the general level of investment in innovation tends to be higher.

7 Conclusions

While the process of liberalising the postal sector was initiated a decade ago in Europe, the impact of liberalisation and competition on efficiency and innovation in the postal sector have not been assessed yet.

This paper aims at contributing to the literature with empirical evidence on the effect of both liberalisation and competition on innovation in the postal sector. The impacts of quantity supplied and private ownership are also analysed.

To this end, a dataset which constitutes a unique source of information for analysing the liberalisation process, the development of competition and the development of innovation in the postal sector in the last decade, is put together. The dataset embraces data for 17 European countries, over 11 years. Three measures are used as proxies for innovation: (1) an innovation index based on the results of a survey developed for this purpose; (2) the accumulated number of innovations (based on that same survey); and (3) labour productivity. We also develop a liberalisation index, which allows us to measure the percentage of market liberalised (in terms of letter volume).

Several models are estimated by GLS. In general, the models estimated have a high explanatory power. We find evidence that market liberalisation has a positive effect on innovation. This finding supports the idea that the threat of competition (or potential competition) on its own induces firms to be efficient. Given the relatively low sunk costs in some parts of the postal value chain, this result suggests that those parts may constitute contestable markets in the sense of Baumol et al. (1982).

We also find evidence that an increase in the market share of the competitors stimulates the investment in innovation, at least until the market share of the competitors reaches a certain threshold. Since competition is not very developed in the postal sector, it is not possible to draw conclusions for the cases where the competitors have a larger market share. Nevertheless, it is also found evidence of the positive impact that mail volume has on the introduction of innovative processes. One can anticipate that if the incumbents lose a considerable part of their market share it will be more difficult to have the means to invest in innovation and to recover the investments made.

The GDP *per capita* turns out to be very significant and to have a positive relationship with innovation in all the models.

Further work could introduce work-sharing (upstream access) and downstream access, as explanatory variables in the model. It would also be interesting to replicate this study for other network industries, in particular, the ones where competition is more developed. Alternatively, the number of countries included in our sample could also be expanded.

Appendix A

Instructions: Please fill in the dates when each of the innovations was introduced into operation. If the innovation was not introduced yet please write “NA”

Innovation	Specificities	Part of value chain concerned	Year of introduction into operation (not test or pilot)	Remarks (Please write here any remarks or notes regarding your answers)
Optimisation of collection routes (using software)		Collection/ transportation		
Hybrid mail [1]		Collection/ all value chain		
Digital stamp [2]		Franking		
Radio frequency identification (RFID):	Used to identify trucks	Upstream/ transportation		
	Used to identify trolleys	Upstream/ transportation		
	Used to identify trays or bags	Upstream/transportation		
	Used to monitor the performance of the letter post [3]	Upstream/ transportation		
Automated sorting machines using Optical Character Recognition (OCR):	That can read all front side of the letter	Sorting		
	That can read hand-written whole addresses	Sorting		
	That can read hand-written postal codes	Sorting		
	That can read machine written postal codes and whole addresses	Sorting		
Video coded address reading equipment [5]:	Online coding	Sorting		
	Scanning and remote coding (off-line video coding equipment)	Sorting		
Automated sequence sorting to delivery route [4]		Sorting/ delivery		

Innovation	Specificities	Part of value chain concerned	Year of introduction into operation (not test or pilot)	Remarks (Please write here any remarks or notes regarding your answers)
Automatic tray handling systems		Material handling		
Automated guided vehicles (AGV) [6]		Material handling		
Route planning and optimization software for delivery		Delivery		

[1] Customers digitally send the information to be printed to the Postal Service Provider, which then sorts the mail electronically, prints it and dispatches it in physical form into the conventional mail stream from the site closest to the delivery point. Conversely, hard copy mail can be scanned in and sent on directly to an online account. Hybrid mail offers particular advantages for direct-marketing and large-scale mailings. Most of the costs involved in the physical handling of traditional paper mail are cut, since the data is handled in real time in electronic form until the final phase of the process, when it is printed on paper and physically delivered to the recipient

[2] A digital stamp, in mail or philately, is similar to a conventional postage stamp except it is resident on or in a computer. A digital stamp can typically be downloaded and printed onto envelopes or packages by authorized individuals

[3] RFID tags monitor test letters at key points in the mail processing pipeline. It highlights bottlenecks so that postal operators can free them and speed up the mail flow. Test letters with RFID tags in them are seeded into normal mail flow and operators do not know which have the tags in them, ensuring objectivity and reliable results

[4] This is a letter sorting system to extend mechanization to delivery route sequencing, the last operation in the processing cycle. The goal of sequencing systems is to automatically sort mail into delivery point sequence with an aim to significantly cut back on the amount of time a letter carrier needs to spend in the office casing mail

[5] Video coded address reading equipment: Unreadable addresses, e.g. cursive not distinguished by the OCR, unreadable machine print or unmatchable to the address database, are digitally imaged and (1) processed by human operators online (online coding), or (2) sent on to a Remote Encoding Centre (REC) and processed by human operators there (scanning and remote coding) (Arthur D. Little Limited 2004)

[6] Automated guided vehicles (AGVs): AGVs are transport systems capable of functioning without driver operation. AGVs are used within sorting offices to move mail around. AGVs find their way without a person behind the wheel by using laser guidance, wall-mounted reflectors, and a computer-based human controller running the routing software. They can also be run on magnetic paths; this does leave less flexibility for maneuver but can be safer when interacting with employees. While the vehicles can be programmed to follow a set route, it is also possible for employees to divert the AGVs if required. The vehicles can determine if there are loads waiting at set points by the change in area contrast and load monitor systems preclude uneven or overloading. Robotics can also be used to sleeve, lid, unsleeve and unlid mail packages at each end of the transportation process (Arthur D. Little Limited 2004)

Appendix B

Table 5 Descriptive statistics

Variable		*Mean*	*SD*	*Min*	*Max*	Observations
Country	Overall	9	5	1	17	$N = 204$
	Between		5	1	17	$n = 17$
	Within		0	9	9	$T = 12$
Year	Overall	2001	3	1995	2006	$N = 204$
	Between		0	2001	2001	$n = 17$
	Within		3	1995	2006	$T = 12$
mktliberalised	Overall	34	37	0	100	$N = 204$
	Between		37	3	100	$n = 17$
	Within		9	12	105	$T = 12$
mktshareE	Overall	2	2	1	11	$N = 187$
	Between		2	1	8	$n = 17$
	Within		1	−2	6	$T = 11$
publick	Overall	95	17	10	100	$N = 204$
	Between		17	34	100	$n = 17$
	Within		6	64	118	$T = 12$
tvolume	Overall	6	8	0	29	$N = 187$
	Between		8	0	27	$n = 17$
	Within		1	4	8	$T = 11$
popdens	Overall	120	95	15	393	$N = 187$
	Between		97	15	383	$n = 17$
	Within		2	109	130	$T = 11$
gdppercap	Overall	15	11	1	38	$N = 187$
	Between		11	1	36	$n = 17$
	Within		1	9	19	$T = 11$
inindex	Overall	−5	5	−15	5	$N = 204$
	Between		4	−11	3	$n = 17$
	Within		2	−10	2	$T = 12$
accuminno	Overall	6	4	0	13	$N = 204$
	Between		3	1	10	$n = 17$
	Within		3	0	14	$T = 12$
itemperempl	Overall	66	41	4	166	$N = 187$
	Between		41	7	133	$n = 17$
	Within		12	31	103	$T = 11$

Table 6 Correlation matrix

	mktliberalised	mktshareE	publick	tvolume	popdens	gdppercap
mktliberalised	1					
mktshareE	0.5438	1				
publick	0.0409	−0.1267	1			
tvolume	−0.1522	0.0063	−0.1549	1		
popdens	−0.3423	−0.1162	−0.7258	0.462	1	
gdppercap	0.1220	0.1336	−0.2803	0.4819	0.3787	1

Table 7 Summary of the heteroskedasticity and correlation tests performed

Dependent variable	Explanatory varibles	Likelihood-ratio test for heteroskedasticity	Modified Wald test	Wooldridge test
inindex	X_{it}	LR $\chi(16) = 88.38$	$\chi^2(17) = 5720.62$	$F(1, 16) = 85.61$
		Prob $>\chi^2 = 0$	Prob $> \chi^2 = 0$	Prob $> F = 0$
accuminno		LR $\chi(16) = 113.16$	$\chi^2(17) = 682.77$	$F(1, 16) = 67.11$
		Prob $>\chi^2 = 0$	Prob $> \chi^2 = 0$	Prob $> F = 0$
itemperempl		LR $\chi(16) = 312.75$	$\chi^2(17) = 87332.65$	$F(1, 16) = 95.70$
		Prob $> \chi^2 = 0$	Prob $> \chi^2 = 0$	Prob $> F = 0$

Table 8 Results of GLS estimation with inindex as dependent variable

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
$mktliberalised_t$	0.009	0.017	0.037	0.040			
	(1.07)	(1.79)*	(3.74)***	(3.81)***			
$mktshareE_t$	0.351	0.375	0.478		0.645	0.525	0.388
	(4.83)***	(4.26)***	(6.37)***		(8.21)***	(6.68)***	(4.43)***
$publick_t$	−0.108	−0.093	−0.087	−0.094	−0.073	−0.075	−0.072
	(4.80)***	(26.89)***	(11.97)***	(11.07)***	(9.97)***	(8.77)***	(11.36)***
$tvolume_t$	0.084	0.090	0.298	0.259	0.252	0.384	0.237
	(1.46)	(1.37)	(8.88)***	(7.25)***	(12.17)***	(3.82)***	(7.25)***
$popdens_t$	−0.021						
	(2.94)***						
$gdppercap_t$	0.304	0.192					
	(3.84)***	(2.51)**					
$mktliberalised_{t+1}$						0.016	
						(2.02)**	
$mktliberalised_{t-1}$							0.019
							(1.64)*
Constant	2.436		−1.127	0.142	−0.895	−1.492	−0.591
	(0.97)		(1.91)*	(0.26)	(1.68)*	(1.83)*	(1.33)
Observations	187	187	187	187	187	187	170

Table 8 continued

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Log likelihood	1192	–	–	1171	–	1215	1264
Wald chi2	379	1108	219	213	192	210	148
Prob > χ^2	0	0	0	0	0	0	0

Absolute value of z-statistics in *parentheses*
* Significant at 10% level; ** significant at 5% level; *** significant at 1% level

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